NEWSLETTER

PRIVATE CIRCULATION VOLUME 12 NUMBER 3 SUMMER 1975

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AUSTRALIAN SOCIETY FOR LIMNOLOGY
NEWSLETTER

VOLUME 12 NUMBER 3 SUMMER 1975

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THE AUSTRALIAN SOCIETY FOR LIMNOLOGY

The Australian Society for Limnology is an association of over 200 people with professional or amateur interests relating to Australian inland waters. Since its inception in 1961, the Society has played an important role in fostering limnological work in this country. The ASL also promotes liaison between limnologists in academic, private, and governmental institutions, and has a vested interest in the conservation of aquatic and related resources. Annual congresses are held near centres of limnological interest, and the program includes scientific sessions, field excursions, and social activities.

The ASL publishes a Bulletin, containing scientific articles, a Newsletter, with notes on activities, articles of general interest, book reviews, and congress announcements, and also an occasional Special Publication. A further periodical publication is the Directory of Australian limnologists.

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Newsletter contributions are always welcome, and correspondence should be addressed to the Newsletter Editor. The next copy deadline is 28 March 1975.

1975 JOLLY AWARD

Nominations are now invited for this year's Jolly Award. Please send your letter of nomination, seconded by another member, to the Secretary-Treasurer (address on page 2), who will pass it along to the Award Committee for consideration.

CANBERRA CONGRESS

Planning is now well-advanced for the XIV Congress to be held in Canberra from 9-12 May. Accommodation has been arranged at Burgmann College, and meetings probably will be held at the Research School of Biological Sciences, Australian National University.

Interleaved with this issue of the Newsletter are two forms: an application for registration (requiring payment of a $5 fee), and a notice of intention to present a paper at the meeting. PLEASE GIVE THESE YOUR URGENT CONSIDERATION, AND RETURN YOUR APPLICATION TO THE ORGANIZERS BY NO LATER THAN 21 MARCH. The deadline has been advanced to allow for the late appearance of this issue - entirely the Editor's fault (see Limnolore)!

PROVISIONAL PROGRAMME

Friday night, 9 May		registration 2030-2200 hrs, central desk, Burgmann College, ANU campus. Those wishing to attend the formal dinner ($7) and the evening at Gundaroo ($7.50) should pay at this time.
Saturday, 10 May	0900	papers
	1230	lunch
	1400	papers
	1700	end of session
	1900	predinner drinks, etc.
	1930	formal dinner, Burgmann College
Sunday, 11 May	0900	papers
	1030	Annual General Meeting
	1230	lunch
	1400	excursion, probably to Tuggeranong, escorted by personnel from the Dept. of the Capital Territory and the National Capital Development Commission, to view an area marked for future expansion of Canberra.

Congress programme, cont'd.

Sunday, 11 May, cont'd.

1700	return to Burgmann College
1830	coach to Gundaroo Hotel for dinner and entertainment. A splendid time is guaranteed for all.

Monday, 12 May — morning free for collecting etc., but members may be interested in a tourist boat cruise ($2.50) on Lake Burley Griffin.

* * * * * * * * *

Accommodation: as mentioned, most of our accommodation needs will be met by Burgmann College, although there is only limited room for couples. The student price for full board is $7.50, and otherwise $12.50 per day.

Enquiries: if you have any problems, or need further information, the best bloke to contact is Warren Nicholls at the Department of the Environment and Conservation, Canberra. Warren's phone no. is (062) 48 7322, extension 48.

Travel: as mentioned in the last issue, no group travel plans have been made by the Congress organizers, and it is left to individuals to make their own arrangements. It may be a good idea if those living in Sydney and Melbourne contacted each other to see if group arrangements are possible.

Any further plans for the meeting will be advised in the next Newsletter, due shortly before the Congress.

ASL LETTERHEAD

A design for the ASL letterhead has now been adopted, and the official stationery is in use. The design consists of a drawing of Neoceratodus - the Australian lungfish - set in the upper left hand corner, with the words "Australian Society for Limnology" across top centre of the page. Thanks to Joan for her efforts in producing the new symbol of status!

ARTICLES

BOTTOMLESS LAKES IN MORE DEPTH

by Brian Timms
Avondale College, Cooranbong, NSW 2265

In the last issue of the Newsletter I mentioned that the widely quoted maximum depths for Lakes Barrine and Eacham originated during the war (Second World War) "when some Yankee servicemen used a marine echo sounder on the lakes". However, in reading old literature on the lakes, I find that like the depth data, this too is invalid, for Ball (1931) records the depth of Barrine as 360 ft - the figure supposedly obtained by the servicemen. The figure of 480 ft for Eacham probably was also known in 1931.

The maximum depths of 480 ft (= 146 m) for Eacham and 360 ft (= 110 m) for Barrine are recorded in at least four popular accounts that I know of and in three scientific works. In one of the latter not only were the figures quoted without documentation, but they were transposed! Some writers, sensing the lack of authenticity, have not stated precise depths, but mentioned that the lakes were a few hundred feet deep (e.g. de Keyser 1972) or as being greater than 100 m deep (Bayly and Williams 1973). This approach is the only reasonable one in view of the unknown source and accuracy of the widely believed depths. However, in searching for the origin of the figures I came across a report by Mr A. Goulet (in Jardine 1925) to the effect that he had measured the depth of Eacham at 226 ft (= 69 m). This figure agrees, within the limits imposed by wide seasonal fluctuations in water level, with my own figure of 65.5 m (Timms, in press). In view of the lack of documentation on other quoted depths (for Eacham: 360, 480, and 500 ft), Goulet's figure should have been believed until more recent data became available, and not treated as an equal "assumption" as did de Keyser and Lucas (1968).

Herein lies a moral for us all: Search ye the literature diligently; believe not in cunningly devised fables.

I would be pleased to hear from anyone who knows of the origins of the widely believed maximum depth figures for Lakes Barrine and Eacham.

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WHY BIG BUSINESS HAS GONE FISHING DOWN ON THE FARM

by Richard Milner

(This article was brought to the Editor's attention by Bill Williams, while on sabbattical in Britain last year. It first appeared in The Sunday Times, London, on 4 August 1974, and is reprinted here with kind permission of the publishers, Times Newspapers Ltd.)

Next year Unilever could be harvesting 150 tons of Atlantic salmon from a sea loch in Inverness. British Oxygen should turn out 120 tons of Rainbow trout from its Vortex plant in Cumberland. ICI and others will be hitting the UK market with 10m Pacific Oysters. And Yorkshire farmer Bruce Falkingham reckons to gross around 1000 pouns sterling an acre on his Dinklesbuler carp crop. Fish farming, which until recently catered primarily for chaps with fly rods, is now beginning to gather momentum as a serious business.

Dr Ian Anderson, monitoring Unilever's million-pound plunge into aquaculture, is highly enthusiastic about salmon farming prospects in Scotland. "No one knows what level annual national production would reach but it is unlikely that it would be less than 10,000 tons and could possibly be as high as 20,000 tons," he comments. And though market forces could check expansion in the short term, even his low guesstimate would represent a 15 million pounds a year industry for the Scottish Highlands.

If Dr Anderson turns out to be only half right, we would still save a tidy sum in foreign currency. Approximately 3,000 tons of wild Atlantic salmon are caught in Britain and Ireland each year but, even so, we normally import an extra 4,000 tons of Pacific salmon. Import substitution could add up to big business in this sector, to say nothing of increasing prospects for exports of smoked salmon.

At present, the average world citizen tucks away something like 26lb of fish every year. Recent estimates by the international Food & Agriculture Organisation suggest that fish consumption will

be stepped up to around 30lb per head by 1980 and to 36lb by the turn of the century. Taken in conjunction with the expected world population increase, this means that global demand for fish could increase from the present 70m tons to 128m tons by the year 2000.

Naturally enough, fish farming has so far evolved mainly in areas without a strong tradition of sea fishing. Counting everything from abalone to yellow-tails, the FAO estimates that the world output of farmed fish currently amounts to some 4.5m metric tons. Half of these home grown fish are raised in mainland China (2.24m tons), followed at some distance by India (480,000 tons) and Russia (190,000 tons).

Britain does not feature in the world fish-farm league, for the simple reason that nobody has managed to work out an accurate figure. Crude estimates suggest that UK fish farms currently produce maybe 800-900 tons of trout for the table (as opposed to the trout lake), plus 50-100 tons of salmon and 1,000-odd tons of oysters.

To put this in perspective, a modern stern trawler like Associated Fisheries "Pict" can land 350 tons of fillets from a single 60-day voyage. (Its total catch would originally have weighed in at close to 1,000 tons.)

While the sea provided an apparently limitless supply of fish for the netting, fish farming was left to hungry monks, eccentric foreigners, and fanatical sportsmen. Now some of the best grounds are fished out or fenced off, factory ships are having to range farther and catch faster, and food processors are less than totally enchanted with the commercial possibilities of deep sea exotics like the grenadier (alias ratfish) as substitute fish-finger material. It is for these reasons that outfits like Bookers, Fitch Lovell, Rank Hovis, and Unilever have gone fishing themselves.

Before swift rail transport brought sea fish to everyone's doorstep, Britain (like other European countries) had developed a system of freshwater carp husbandry in "stew ponds". Carp had several advantages as a food fish. For a start they were quite good eating with plenty of flesh and not too many bones. They were undemanding in their feeding habits, resilient to seasonal temperature changes and (not least important) could be kept alive for days out of water and so could be sold fresh even in a distant market place. UK carp-keeping declined sharply after the industrial revolution but the new technological revolution has shown that fish have another important "plus".

Factory farming techniques have emphasised maximum output for minimum input. Food conversion is the name of the game. Despite considerable scientific assistance, however, some domesticated animals are still relatively poor converters of food. The average bullock, for example, consumes perhaps 3 tons of feedstuff to reach a bodyweight of 10 cwt - a "food conversion ratio" of six to one. Even with the broiler chicken, technology has failed to reduce the food conversion ratio to below 2½ to one. With feed prices rising and profit margins tighter, such calculations can be critical.

Fish are the answer to a factory farmer's prayer. Cold-blooded and moving fairly effortlessly in their environment (the pressure in their air bladders helps them resist the force of gravity), they do not burn up much energy keeping warm or rushing about. In other words, they are splendid food converters. Flesh-eating cannibals like Rainbow trout can grow to pounders on an input of 1½lb of dry feed. And with vegetarians like carp, able to get by on waterweed and other pond junk, the food conversion ratio can be reduced to a neat one to one. (!)

The Scots have been incubating salmon eggs since 1838 but this splendidly commercial aspect of fish physiology seems to have excaped their attention until fairly recently. Unilever is now making up for lost time. It started investigating the potential of marine fish farming back in 1965, researching through various types of flatfish, crustaceans and salmonids before opting for the Atlantic salmon as its first choice in 1968. Salmo salar was a high price quality fish, demand was likely to be sustained and some forecasters expected reduced landings.

Under managing director Harry Howard, Unilever's offshoot Marine Harvest has solved the problem of transferring one- or two-year old "smolts" from their nursery at Invergarry and raising them in 30-ft-square pens in the vigorous waters of Lochailort (one set of pens sank without trace in a storm) to sell two or three years later as "grilse" or salmon weighing between 6lb and 18lb. Production is scheduled to double from 50 tons to 100 tons this year with a potential of perhaps 150 tons, without any other lochs that may be staked out.

Unilever has been able to slot Marine Harvest quite neatly into its overall food operation, marketing the larger fish under its Lochinvar label and accelerating a programme to improve sales of salmon cuts through multiple outlets like Marks & Spencer. While it has felt its way methodically into fish farming, the process (perhaps inevitably) lacks factory precision. Salmon are capricious animals, developing at varying rates for no obvious reason and resisting attempts to maintain peak food conversion by delaying sexual maturity. Moreover, the hatch-to-despatch schedule is protracted.

Though also leaning heavily on technological expertise, British Oxygen (BOC) has adopted a strikingly different approach. At first it seemed uncertain whether its Project Shearwater at Cowthwaite was designed primarily to show off the oxygen producing Vortex system, which it makes under licence, or simply to make a crock of gold out of Rainbow trout. Since taking the plunge as recently as May last year, however, BOC has swung its emphasis towards intensive, tightly controlled and market-oriented fish production. It works on a 12-month production scedule, turning out 6-8 oz trout strictly for the "table market".

Using a system of biological filters and recycling to maintain water temperature for optimum growth, BOC reckons to be able to produce 8lb of trout per cubic foot of production space compared with only 1lb by more conventional methods. It is one of the more spectacular aspects of this business that anyone with 50,000 pounds to invest could theoretically raise 200 tons of trout a year on a

mere half-acre. As a rule of thumb, trout farmers should brace themselves to lose one harvest in five through natural disaster. "I still see no reason why you shouldn't show a return of between 30% and 35%," comments project manager Chris Bett.

Further Vortex units are sceduled for Australia and six other overseas sites. And BOC also has a 20% stake in Calaqua of California where Dick Klosterman is planning to raise channel catfish to 1½lb pan-weight over a 4-6 month maturity cycle with some artificial assistance (one of the two spawning periods is induced) and the natural stimulation of water emerging at 115 deg F from a 1,031 ft deep well. Within two to five years ("It's a hustling operation") Klosterman aims to be producing 25,000 lb of this ugly but up-and-coming fish a week plus 2,500 lb of the smoked product.

Previously rated as a muddy-tasting Negro food, catfish have been improved in taste and upgraded in status in the US. Farm production is now running at around 40m lb a year. AEO Systems of Lantana near Palm Beach recently invested $2.5m to install 10 massive rearing tanks that will be capable of turning out 8m lb annually by next July. And while catfish are moving up-market, Cohoe salmon are being remodelled for mass consumption. Union Carbide subsidiary Domsea Farms are currently producing 250,000 Cohoes a year from Puget Sound in Washington State. Pan-size twelve inchers.

It is America, too, that technology is accelerating fastest. With domestic shrimp production on the increase, Ocean Protein has invested $2m in a controlled underwater unit in Jamaica designed to produce a staggering two tons of shrimps per acre each year - several times the production rate of a traditional Far East prawn pond. And Marine Protein Corporation of New York is investing $2.5m in huge 20,000 gallon vertical silos for fattening trout, salmon, and striped bass in sea water. Its research shows that trout can be raised to marketable size (10 in) in just six months.

UK fish farming is not developing at quite such a hectic pace. But big names are now moving into this erstwhile small-business. Booker McConnell, whose previous experience of fish was restricted to shrimp trawling in Guyana, recently bought a 70% stake in Highland Trout of Otter Ferry. It has now embarked on what is officially described as a "pilot project" to rear salmon in sea pens at South Uist. Imperial Metal Industries, an ICI subsidiary, has been working with the Highlands and Islands Development Board to produce seed oysters at Scottish Sea Farms up at Ledaig near Oban.

Fitch Lovell's offshoot Golden Sea Produce plans to spend "substantial sums" to build commercial units for raising sea flatties like plaice, sole, and turbot in the warm water outflow of Hunterston power station alongside the experimental units pioneered by the White Fish Authority. It is also looking at salmon-rearing recently bought Poole Oyster (developing Japanese oyster culture in Southhampton Water) "to widen its interests in aquaculture". Its purposive expansion into plaice farming in ordinary sea water at Ardtor suggests that the WFA has made its point. "We ought to be able to produce more cheaply than the fishing industry," comments director Clement Keevil.

Shell has got into the action by buying a half-share in Gateway West of Argyll, one of Scotland's biggest trout farms turning out some 200 tons of fish a year, with diversification into salmon under way. At the other end of the spectrum Bruce Falkingham and his partner Vilis Michaels of Newhay Fisheries are tending five carp pools on 2½ acres of Yorkshire water meadow, reckoning to fatten those Dinklesbülers to around 4lb to 5lb over two and a half years mostly for sale at premium prices to immigrant Britons from Middle Europe. "They must have one of these fish - at least at Christmas," Falkingham explains. "It's like turkey to us."

Unexpected disease, pollution, and/orclimatic upsets can spell disaster for the aspirant fish farmer, of course. "There's a lot of money and initiative going into the business at the moment," comments Chris Bett of BOC. "It's the ones with the technological solutions who will come out on top." Bruce Falkingham is confident that he is on to a good thing. His Dinklesbülers have 30% less bone than other carp, they thrive on chicken giblets, waste corn, and other farm rubbish, they will multiply his return per acre ten-fold and local power stations have already shown a lively interest in the fact that in warm water outfalls they can grow to 3½lb within twelve months.

As Britain's new fish farmers move out of the laboratory and into the market place, both Shell Petroleum and Newhay Fisheries will play a part in the inevitable development of factory fish production as a necessary source of (relatively) cheap food. Worldwide, long term demand could be colossal. By 2000 A.D., the US Department of Commerce estimates, global fish farm output could increase from the present 4.5m tons to top the 40m ton mark.

DOES ARTEMIA OCCUR IN AUSTRALIA?

by Michael Geddes

Department of Zoology, University of Adelaide

The brine shrimp Artemia is generally stated to be a cosmopilite. Records from the other four continents are frequent and reliable, but the Australian records of the genus are sporadic and in some cases quite doubtful. Many may be mis-identifications of the Australian endemic genus Parartemia.

Artemia was first recorded by King in 1855 in salt pans near Sydney. No adequate drawings were published and no further records from the area are available, and so King's record remains unconfirmed. The next description of Artemia species was provided in 1903 by Sayce, who named two new species, A. australis from Glenelg, South Australia, and A. westraliensis from Murchison, Western Australia. Sayce's records of Artemia may be expected to

be more reliable, as in the same paper he described the new genus Parartemia, to receive the species P. zietziana. However, the two Artemia species were described from juvenile and female specimens only; no males were collected. In the case of A. westraliensis only two female specimens were available. The most obvious difference between the two genera is the form of the male second antennae, used to grasp the female prior to mating, but as Sayce had no males to study he was unable to use this feature. Female specimens may be identified quite easily by the presence of a tall spine on the labrum of Parartemia, but Sayce overlooked this character when describing P. zietziana. Rather he stated that the major difference between Parartemia and Artemia females was the shape of the egg sac. In P.zietziana, the only species of Parartemia seen by Sayce, the egg sac has two large dorsally-directed lobes, whereas in Artemia the egg sac is single and ventral. However, species of Parartemia have subsequently been described with variously shaped egg sacs and so this feature is not truly diagnostic. It is possible, therefore, that either or both of these supposed Artemia collections may have been Parartemia.

Although many authors, including Henry (1924), Daday de Dees (1910), and Linder (1941) list the above records of Artemia, and state that Artemia is a cosmopolite, there were no further literature records of the genus in Australia until 1959 when Edward and Watson recorded Artemia from salt lakes on Rottnest Island, Western Australia. Further specimens from this locality confirmed that salt lakes there are inhabited by a population of female Artemia which reproduce partheogenetically. The present author recently has seen two further collections of Artemia. A parthenogenetic population is present in the salt pans at Shark Bay, Western Australia, and a sexually reproducing population with about equal numbers of males and females is present in the commercial salt pans near Bowen, Queensland. These three populations are the only confirmed records of Artemia in Australia, and all three are from areas where salt is produced commercially. It would seem likely that each represents a recent independent introduction of Artemia to this country.

The fact that the Western Australian and Queensland populations are from different stocks, one parthenogenetic and the other sexually reproducing, and the fact that Artemia has not been collected from inland Australia, supports the conclusion that although Artemia presently occurs in several salt works, the genus may have been introduced only recently.

At the time of writing a parthenogenetic population of Artemia has been located in the Dry Creek saltworks near Adelaide. This locality also has populations of Parartemia, and it will be interesting to study the distribution of the two genera in the saltworks, and establish whether competition will lead to the displacement of one or the other.

I would be very pleased to see any collections of brine shrimp that any members may have, so that the present distribution of Artemia can be more fully clarified.

ADELAIDE ARRIVES ON THE SCENE

As most members will know, Bill Williams has this year taken up the Chair of the Department of Zoology at the University of Adelaide. Two other new arrivals on the staff are Michael Geddes, from the University of Queensland, and Keith Walker, from ANU. John Bishop, one-time student of Noel Hynes at Waterloo, is a Senior Teaching Fellow, and Rod Buckney from the King's lab in Hobart is soon to arrive as a Postdoctoral Fellow. Richard Marchant has followed Bill across from Monash, to complete the remaining year of his doctoral studies, and several Honours Students (Martin Caon, Peter Ghent, and Brad Mitchell have already been indoctrinated into limnological pursuits.

Because things are rather hectic for all those in the new group, they might be forgiven for not contributing some notes on research plans and interests to this issue - this will be rectified in the future!

Note that all Newsletter correspondence should now go to Adelaide rather than Canberra.

The Department of Zoology at Adelaide has applied for admission to the ASL as a sustaining member.

RIVER MURRAY STUDY

The operations of the River Murray ecological survey at Albury-Wodonga have intensified with the arrival of new staff and the provision of additional finance by the Development Corporation. Terry Hillman will assist Roger Croome in the general running of the survey program, and a supporting chemist will soon be appointed, together with additional technical staff. A report detailing the first ten months' progress (from October 1973 to August 1974) was recently published by the Cities Commission, but unfortunately is for limited distribution only. Most of this work, however, will be published in scientific journals in the not-too-distant future.

TRICHOPTERA

Arturs Neboiss (National Museum of Victoria) has recently returned from long service leave, spent in search for a few more secrets of tricopteran taxonomy in the type collections in Sweden, Germany, and Austria, and in attending the First International Symposium on Trichoptera at Lunz-am-See, Austria. Back home, Arturs learnt that he'd been awarded an Australian Biological Resources Study grant to further his work on the Tasmanian fauna. A field trip to Tasmania recently yielded a new family, but the weather was so cold, you could see ice forming on caddis wings in flight!

CSIRO DIVISION OF PLANT INDUSTRY, CANBERRA

(A number of related projects concerned with water quality and primary production in aquatic ecosystems are underway at CSIRO Plant Industry. The following report is an abstracted, slightly modified version of one given at a meeting on Water Management Research, held at CSIRO Head Office, 14-16 May 1974. This material was kindly made available to us by Dr John Kirk and his colleagues.)

PHOSPHORUS AND EUTROPHICATION IN SOME INLAND WATERS (J.T.O. Kirk and C.H. Williams)

In order to determine to what extent phosphorus is a limiting nutrient in Australian inland waters it will be necessary to measure phosphate levels of a variety of water bodies and correlate these analyses with measurements of other crucial parameters such as plant biomass, oxygen content, etc. We have begun a programme of research on this topic, and will refer here to some of our preliminary results.

Waste water from Canberra (population ca. 180,000) is discharged after treatment into the Molonglo River which, about 10 miles downstream, joins the Murrumbidgee River at Uriarra Crossing. About 20 miles further downstream the Murrumbidgee flows into Burrinjuck Dam, a water storage which is of major importance for the Murrumbidgee Irrigation Area, and is much used for fishing, water ski-ing, and other recreational activities by people from Yass, Canberra, and surrounding districts. Downstream of the dam the river water is used for domestic supply by a number of shire councils.

We found the level of reactive soluble phosphorus in the Murrumbidgee above the Molonglo inflow to be very low indeed - about 2 µg/l. At a point about 300 metres below the confluence with the Molonglo the water contained 228 µg/l of inorganic P. It thus appears, not surprisingly, that Canberra sewage is greatly increasing the phosphate content of the Murrumbidgee. Our main interest, however, is not so much the effect on the river as on the dam. We have therefore recently (February 1974) carried out some measurements of reactive soluble P in water samples from Burrinjuck. In the Murrumbidgee Arm, where the river enters, 99 µg/l was found; at two other points, at increasing distances away from the river entrance, concentrations of 42 and 24 µg/l were found. These values are all high, being above the danger mark of 20 µg/l, and indicate that Burrinjuck is receiving an excessive input of phosphorus. Later measurements, in winter 1974, showed 63 µg/l reactive soluble P, 98 µg/l total P, and 300 µg/l nitrate-N (nitrate levels are being studied with Mr P. Jakobsen, CSIRO Division of Land Use Research).

Two other parameters we have chosen to measure are the chlorophyll content, which gives a measure of the algal biomass, and the oxygen content, a measure of the degree to which the oxygen supply of the system is sufficient to cope with the oxidation of the organic matter accumulating as a result of photosynthesis. The chlorophyll *a* content in the euphotic zone we found, in late summer 1974, varies markedly from one spot to another. The reason was the presence of a colonial green alga, provisionally identified as *Botryococcus* sp. This alga has a tendency has a tendency to float to the surface and can form a clearly visible scum which can be concentrated by wind action. The average of a number of samples taken at depths of 0.5 and 1.5 metres (27 February) was 27 ug/l chlorophyll *a*. However, at some points the concentration in the top 2-3 cm was very much higher: one sample contained 360 ug/l chlorophyll *a*. Even the value of 27 ug/l is rather high and is in the same range as chlorophyll values reported for other lakes in the world that are acknowledged to be in a eutrophic condition.

The oxygen measurements tell a similar story: as may be seen in Figure 1, oxygen content is high in the upper levels but falls

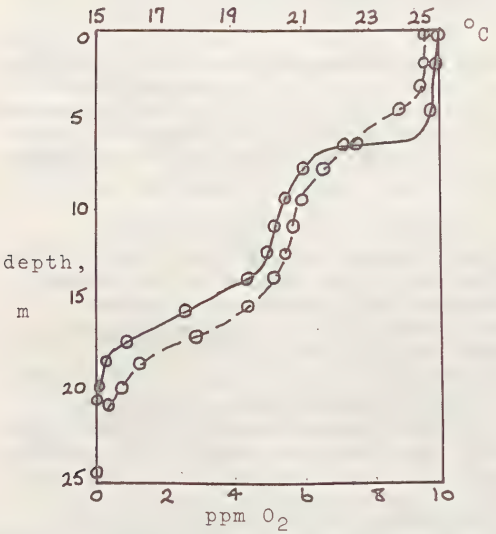

Figure 1. Depth profiles of oxygen (solid line) and temperature (broken line) in Burrinjuck Dam, 23 January 1974.

virtually to zero below about 18 metres. This suggests that organic matter is raining down from the euphotic zone faster than it can be oxidized. The anaerobic conditions in the lower levels could discriminate particularly severely against the more desirable salmonid (e.g. trout) species which in hot weather would otherwise seek to take advantage of the lower temperatures at greater depths.

Measurements of these three key parameters - phosphate, chlorophyll, and oxygen - strongly indicate that Burrinjuck Dam is in a eutrophic condition. This condition can most plausibly be attributed to the input of mineral nutrients in the form of sewage effluent from Canberra. A new and more advanced sewage works (the Lower Molonglo Water Quality Control Centre) is shortly to be constructed. It is intended that this will greatly reduce the contribution of mineral nutrients from sewage effluent to the

Molonglo-Murrumbidgee system. If these expectations are realised, Burrinjuck may in future recover from its eutrophic state.

If we now shift our attention back to the Molonglo, upstream of the Canberra sewage works, we have another interesting system. Here in Canberra we have an artificial impoundment, Lake Burley Griffin. This is of substantial size, being about 7 miles long, but is a purely ornamental/recreational lake, and is also quite shallow, unlike Burrinjuck. A very important difference between Burley Griffin and Burrinjuck is that the water level of the former remains very constant, whereas the water level of Burrinjuck fluctuates considerably in accord with the amount of water taken out for irrigation in the MIA. This means that rooted aquatic plants can become established in the shallow areas and around the margins of Burley Griffin, but do not become permanently established in Burrinjuck.

About 5 miles upstream of Lake Burley Griffin treated sewage effluent from the twon of Queanbeyan (population 20,000) is discharged into the Molonglo. Water in the river above the sewage works we found to have a satisfactorily low dissolved inorganic P content of 6 µg/l. A short distance below the works the level was 233 µg/l. In the lake itself concentrations of reactive soluble P of 56 µg/l (July 1974) and 20 µg/l (November 1974) have been found. The chlorophyll a concentrationin the euphotic layer of the lake we have found to be in the region of 2-9 µg/l: not an excessive level. The oxygen concentration (summer) we found to vary from 7.2 ppm at the surface down to 4.9 ppm at the bottom (7 metres). Being so shallow Lake Burley Griffin does not appear to undergo thermal stratification, and this fact alone should help to prevent the establishment of an anaerobic layer at the bottom.

The dissolved phosphorus content of the lake already is rather high, and no doubt will increase further as the population of Queanbeyan increases. A seriously eutrophic condition may therefore develop in the future. This may however in part be mitigated by the naturally high turbidity of the lake. Even at present the concentration of planktonic algae, indicated by chlorophyll measurements, is lower than the available phosphate could support. The main factor limiting primary production in the lake at the moment could be the availablity of light, a subject dealt with in a subsequent note. A possible additional factor is pollution by zinc originating in the Captain's Flat mines (see note on inhibition of photosynthesis by metal ions).

THE FATE OF SEWAGE PHOSPHORUS (D.J. Cosgrove)

To prevent excessive enrichment of water bodies by phosphorus we need to understand and control the processes and pathways involved in the transfer of phosphorus from the terrestrial to the aquatic environment. A major pathway, of course, is via domestic sewage. The fate of phosphorus in the various steps of sewage treatment to the final waste water discharge is neither fully understood nor fully under control. As a contribution to our understanding of this process the chemical nature of some of the phosphorus compounds in activated sludge is being studied. The

inositol polyphosphate fraction has been shown to consist of a mixture of penta- and hexaphosphates of myo-, chiro-, scyllo-, and neo-inositol. These compounds are absent from raw sewage and appear to originate as a result of biological activity in the aeration process.

CHEMICAL CONTROL OF EXCESSIVE AQUATIC PLANT GROWTH (B.T. Brown and J.N. Phillips)

Control of excessive submerged growth is generally more economical by chemical means than by mechanical harvesting, but currently used herbicides such as acrolein and the bipyridyls are non-selective and may be toxic to fish, stock, and man if not handled correctly. To the present time, most developments in aquatic herbicides have been the result of spin-off from terrestrial agricultural herbicide research and there has been little effort to develop compounds specifically for aquatic weed control.

The current studies are concerned with screening selected organic compounds against a submerged aquatic vascular species, Canadian Pond Weed (Elodea canadensis) and against a free-floating plant, duckweed (Lemna minor). This is carried out in conjunction with detailed studies on the effects of various compounds on the rates of respiration and photosynthesis in submerged species. At present, two chemical classes are of interest. The first has been shown to rapidly increase the plant respiration rate, followed by a complete cessation of respiration. When exposed to the light, plants so treated become chlorotic and die. The second class of compounds are cheimicals analogous to the established bromuracil herbicides and form part of a study of the relationship between inhibition of photosynthesis in aquatic species, chemical and physical properties of the molecule, and the activity in isolated chloroplast systems. The long term object of this work is to provide information which may lead to the development of more selective and efficient aquatic herbicides.

LIGHT AS A LIMITING FACTOR IN PRIMARY PRODUCTION (J.T.O. Kirk)

Of all the physical parameters the electromagnetic radiation field is the one with which we are most concerned, because it is related in the most direct possible manner to primary production. The only source of such radiation that we need consider is the sun. The purely thermal effects of absorption of solar energy by water are important but have been considered earlier. What we are concerned with here is the availability for photosynthesis within water bodies of solar radiation in the 0.35-0.7 μ band, the extent to which this is a limiting factor for total primary production, and the extent to which it can favour certain types of plant over others.

An important point to note is that while a particular nutrient, say phosphate, may indeed be limiting plant growth in the upper layers of a boday of water, as depth increases light intensity falls off and eventually (except in shallow water) must become limiting. Thus we can reasonably say that for waters of any substantial depth,

certain nutrients may or may not limit primary production, but light intensity always limits production in at least part of the water body. In view of the central importance of light as a controlling factor, we have chosen to devote the greater part of our efforts both to the measurement of the light field within water bodies, and to a theoretical understandings of the mechanisms by which the light is attenuated, and its spectral quality altered, as it penetrates to increasing depths within the water.

Essentially all the attenuation of light within a water body can be accounted for in terms of four factors. The first is the absorption of light by water itself; contrary to popular belief water is not a colourless liquid, but a blue liquid with a strong absorption at the red end of the spectrum (Figure 2). This is unfortunate for algae since it means that the red absorption peak of chlorophyll is of little use at depths greater than a few metres: 5 metres of water removes 90% of the light of wavelength 680 nm.

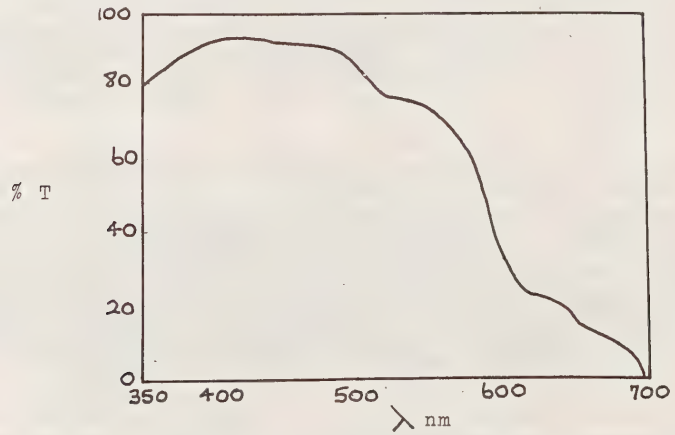

Figure 2. Percent transmission of a 5 metre layer of pure water as a function of wavelength.

The second factor is absorption of light by substances dissolved in the water. In oceanic waters these are of no significance, but freshwater bodies and coastal waters invariably contain significant quantities of substances absorbing in the blue and near ultraviolet. These are collectively referred to by the German term "gelbstoff" ("yellow substance"); they appear to be constituted of plant breakdown products and may well consist mainly of phenolics. The presence of gelbstoff is also unfortunate for algae since it removes the blue light - which the algae would otherwise be able to capture by means of the carotenoid and chlorophyll absorption bands in this region of the spectrum. Since higher plants and many algae absorb light best in the red and the blue, and since much of the red light is taken out by the water anyway, the concentration of gelbstoff can be of crucial importance in determining the potential productivity of, and the type of plants which will thrive in, the water.

The third factor is scattering, and to a lesser extent absorption, of light by inanimate particulate matter suspended in the water. This paticulate matter consists predominantly of silt, suspended mineral particles produced by soil erosion in the catchment area. The turbidity caused by the sediment load can be so high as to virtually abolish light and consequently primary production in the water body. Turbidity, however, is of its nature a very variable phenomenon, and while some waters, particularly in Australia, do seem to be consistently rather turbid, the very high levels of turbidity which develop after heavy rain do not persist very long.

The fourth factor is light absorption by the plant material itself. In lakes of moderate productivity, light absorption by the phytoplankton does not appear to contribute very much to the total light attenuation. However, in eutrophic lakes with high concentrations of suspended algae, light absorption by the algal chloroplast pigments can be of dominating importance: growth of algae at lower depths can be substantially inhibited by the density of algae higher up. Aquatic vascular plants can have a marked localised influence on light intensity. Within a stand of rooted aquatic plants such as Myriophyllum sp. or Potamogeton crispus there will be light attenuation of the same type as may be found in a canopy of terrestrial plants. Floating plants such water hyacinth can intercept most of the light before it ever enters the water.

Experimental studies on light attenuation in natural waters:

We have set out first of all to measure the way in which light available for photosynthesis is attenuated in our local waters, and to determine the contribution of the four different factors referred to above. For our measurements we have used a quanta meter. This is a photoelectric instrument (Lambda Instrument Co.) with its spectral response appropriately corrected to make the instrument reading proportional to the flux of quanta in the photosynthetic waveband. There is now general agreement amongst people in the filed that this is the type of instrument which should be used for measuring underwater light in relation to primary productivity.

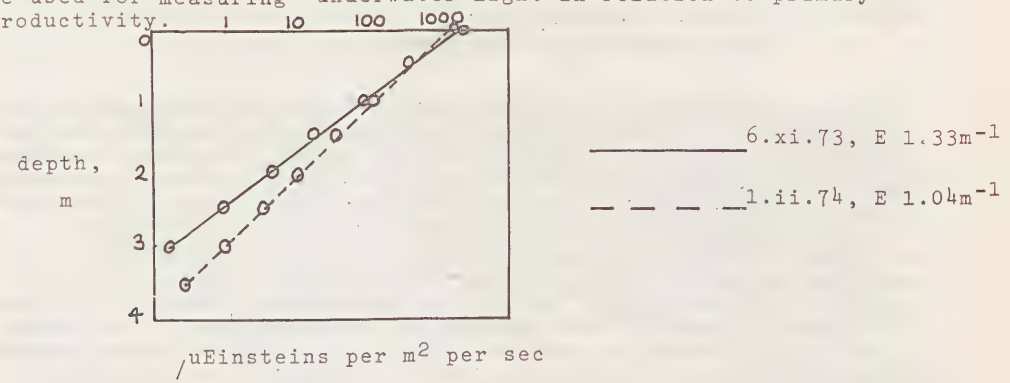

Figure 3. Variation of downward irradiance (measured as quanta in the photosynthetic waveband) with depth in Lake Burley Griffin.

Figure 3 shows the attenuation of light at a particular point in Lake Burley Griffin on two different dates about 12 weeks apart. It is immediately apparent that light intensity diminishes very rapidly with depth, falling to 1% of the surface value at only 1.4-2.0 metres. This means that the euphotic zone was not more than 2 metres deep. Light attenuation in aquatic systems is described approximately by the equations

$$I = I_o 10^{-Ez}$$

and

$$\log_{10} I = -Ez + \log_{10} I_o$$

in which I_o is the light intensity immediately below the surface, I is the intensity at depth z metres, and E is the vertical attenuation coefficient for the water body in question. For our purposes the optical properties of the water may be characterized by the attenuation coefficient E, which might for simplicity be regarded as the optical density of a 1-metre layer. The attenuation coefficient for Lake Burley Griffin was in the range 1.33-1.70 per metre in November 1973, falling to 1.04 at the beginning of February. The November values may have been unusually high because of the turbidity brought down by the heavy winter and spring rains, and so we shall take 1.04 per metre as a more typical value.

We have attempted to assess to what extent each of the four factors discussed above is responsible for this still very high attenuation coefficient. To estiamte the contribution of dissolved solutes (gelbstoff) we filtered some of the water through a 0.22 μ pore size filiter and measured the absorption spectrum in a 5 cm cell aginst a distilled water blank (Figure 4). It can be seen that there is strong absorption in the blue region. Aprroximate calculations indicated that absorption by water, gelbstoff, and algal cells together, in the absence of turbidity, should have given an attenuation coefficient of about 0.3 per metre. Since the

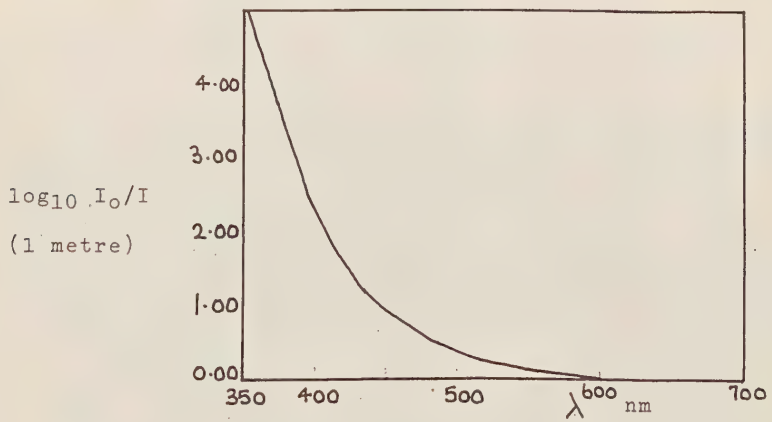

Figure 4. Absorption spectrum of gelbstoff. Optical density of a 1-metre layer of filtered Lake Burley Griffin water (calculated from measurements in a 5 cm cell with a distilled water blank).

measured value was 1.04 it is clear that turbidity due to suspended silt had increased the attenuation coefficient 3.5-fold. Or, to put it another way, the turbidity decreased the amount of light transmitted by a metre of water from about 50% down to about 9%. Nevertheless, it is still the water, gelbstoff, and algal cells which are absorbing the light. The effect of the turbidity is to greatly increase the pathlength of the photons within a given depth of water. It was possible to calculate that in the top 2 metres of Lake Burley Griffin at this time, 34% of the absorbed quanta were absorbed by water, 63% by gelbstoff, and 3% by the algal cells (present at only about 3 /ug/l chlorophyll a). Similar measurements and calculations carried out for Burrinjuck Dam indicated that turbidity was sufficient to double the attenuation coefficient from the calculated value of 0.45 per metre to a measured value of 0.91 per metre. For Burrinjuck it was estimated that of the total quanta captured in the top 2 metres, 23% were absorbed by water, 59% by gelbstoff, and 18% by the algal cells (present at 27 /ug/l chlorophyll a).

What is abundantly clear from these experimental studies is that light intensity in these two inland water bodies falls off very steeply wiyh depth, mainly because of the high levels of gelbstoff, the effect being greatly increased by turbidity. This means that the productive layer is very shallow, and constitutes only a small proportion of the total volume of the lake. In water bodies of this typelight is very much more an important limiting factor for primary production than in, say, oceanic or most coastal waters. Another consequence of this type of light field is that it should give a selective advantage to those algal cells which have the ability to float into the illuminated layer. This may account for the fact that the dominant alga in both lakes in February was Botryococcus, which happens to be the only green alga to possess this ability.

Light requirement for photosynthesis by aquatic plants:

The virtual disappearance of light at quite small depths in these lakes must make it difficult for rooted vascular plants to become established and thrive except in shallow waters. For example, at depths where the light intensity is below its compensation point - the light intensity at which photosynthetic oxygen output is just equal to respiratory oxygen uptake - a seedling will simply be unable to grow once it has exhausted its seed reserves. Even when plants succeed in becoming established, a sudden diminution in light intensity due perhaps to increased turbidity brought in by flood waters could cause them to die off. To understand what plants will be able to grow in particular aquatic habitats it is necessary to know not only the intensity and spectral composition of lightin the habitat, but also the extent to which particular plants can make use of light of various intensities and spectral qualities.

We have recently investigated the ability of leaves of two common rooted aquatic plants, Potamogeton crispus and Vallisneria spiralis, to photosynthesise in various intensities of white light. The rate of photosynthesis (determined manometrically) falls off progressively with decreasing light

below about 300 /u Einsteins.m^{-2}.sec^{-1} (Figure 5), and there appears to be no net oxygen evolution below about 9 /u Einsteins. m^{-2}.sec^{-1} (approx. 50-60 foot candles). In Lake Burley Griffin

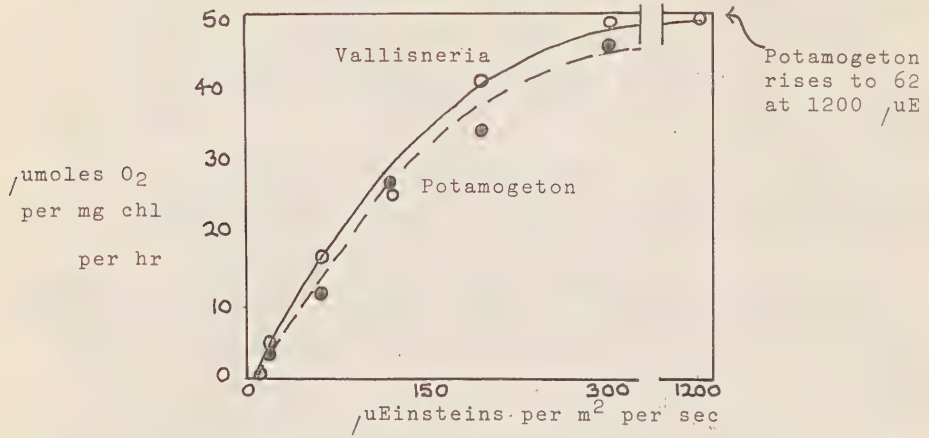

Figure 5. Rate of photosynthesis as a function of light intensity in leaves of Vallisneria spiralis and Potamogeton crispus.

in the spring and early summer of 1973 light intensity even on sunny days in the middle four hour period fell to this level at depths of only 1.5-2.0 metres. Both the species can in ideal circumstances grow in depths of 4 metres or more. It seems likely that their ability to colonize Lake Burley Griffin, a considerable proportion of which is less than 4 metres deep, might be seriously limited by the rapid attenuation of light with depth. Any marked reduction in the turbidity of the lake waters in the future could greatly increase the area occupied by these, and other, water weeds.

INHIBITION OF PHOTOSYNTHESIS IN SUBMERGED VASCULAR PLANTS (B.T. Brown)

In spite of the extensive literature on the toxicity of heavy metals to freshwater algae, there is little information on the toxicity of these ions towards submerged vascular plants. High levels of metal ions in waterways usually arise as the byproduct of industrial activity, either from effluent which is intermittently or continuously discharged during a manufacturing process, or leached by rainfall from mine dumps or slag heaps. Either process can give rise to high and sustained levels of a specific metal ion in flowing water and in the sediments of these waters.

The present studies are concerned with the effects of dissolved metal ions on the potential photosynthesis in representative submerged aquatic species such as Elodea canadensis, Potamogeton crispus, and Vallisneria spiralis. These three species are widely distributed in free flowing waters in Australia and on the shorelines of dams and lakes at depths up to 3 metres.

Present work involves exposure of plant material to concentrations of various metal ions and then observing the photosynthetic ability of these plants (as measured by oxygen evolution) under standardised conditions. Copper, zinc, nickel, lead, mercury, and silver have been examined to date with copper, silver, and mercury being the most toxic. For example, after 24 hours exposure 0.1 ppm Cu will reduce the photosynthetic rate in Elodea to 50% of that of untreated plant material, whereas 0.3 ppm will reduce photosynthesis to only 10% that of untreated plants. While these values are considerably higher than those of unpolluted river water, they are less than the 1 ppm allowable limit for drinking water recommended by the US Department of Health, Education, and Welfare.

It is proposed to study these effects with both continuous and intermittent exposure to metal ions over various time periods, to gain an idea of the levels of metal ions in waterways that will inhibit photosynthesis with a consequent inhibition of plant growth and development.

METHODS OF COLLECTING & PRESERVING BLEPHARICERIDAE (Bill Williams)

Members who attended that marvellous congress and AGM at Narrandera, NSW, a few years back will perhaps remember the request made there by Dr Peter Zwick, a visitor from Western Germany, for specimens of the net-winged midges (Blephariceridae, Diptera). The larvae of this family are characteristic of rapidly flowing streams, and the adults, though aerial, are similarly associated. Peter has now completed a very large manuscript on the group and this will shortly be submitted for publication. The manuscript - though monumental! - does note that probably only a small percentage of the fauna of northern NSW and Queensland is yet known. Even in south-eastern Australia, which area was most intensively studied by Peter, several species cannot be described adequately because of lack of material, and various faunistic, bionomic, and ecological problems have scarcely been scratched. For these reasons, it might be of some use and interest if members had access to some notes that Peter has prepared on methods of collecting and preserving adult and larval 'blephs'. These are reproduced below.

"Adults can be swept with a net or can be hand-picked from their resting places; a puter (aspirator) is also very useful.

To obtain immature stages, which are often more readily and more reliably identified than adults, it is normally necessary to remove stones temporarily from the stream. Larvae and pupae are then picked off with forceps. While the ventral suckers of larvae are fairly easily detached from the substratum, pupae are firmly attached to it and must be removed with great care. Tweezers made of flexible steel as used for watch springs are very suited for this. Used sideways, they have the properties of an extremely flexible knife and can well be used to detach and pick pupae.

Often, the most suitable places for the immatures are rocks too large to be removed from the stream. Any specimens detached under water are usually immediately swept away by the strong current these animals prefer. In such cases a net must be placed below the stone in such a way that larvae and pupae rubbed off with the bare hand or scratched off with flexible forceps are washed into the net. To collect the genera Apistomyia and Austrocurupira, it will at times be necessary to work in the middle of a waterfall!

Blephariceridae can be found throughout the year, but the greatest diversity of species is met in spring and early summer. Attention should always be paid to rocks just above the water surface, as they are at times covered by dead pupae which have dried out because of falling water levels before hatching of adults. This may prove the occurrence of a species at a given locality even months after its flight period, when it cannot be found in the stream.

Larve and pupae are not randomly distributed over the stream bed but concentrate in a few suitable places, mainly determined by current conditions. The collector will learn to recognize these from the aspect of the stream surface. This, however, may change radically with even slight changes in water level after heavy rains and become entirely misleading. As larvae are slow-moving, they are obviously unable to follow such short-term alterations of water level and current conditions and are then hard to find.

All material collected should be preserved in fluid, preferably alcohol. I recommend undiluted alcohol (methylated spirits will do),as large amounts of water are inevitably brought into the vials together with the immature stages. This will bring down the alcohol concentration to 80% or 75%, which I find better for storing than the frequently recommended 70%."

SOUNDS OF CORIXIDS

Ian King (Zoology, ANU) has recently completed a Masters thesis entitled "Underwater sound production in Micronecta batilla Hale (Heteroptera, Corixidae), and his kindly consented to the abstract being reproduced for the Newsletter.

Males of Micronecta batilla Hale produce three types of sound; females do not stridulate. "Chirps" consist of 30 to 45 pulse-trains regularly spaced 22 ms apart. "Clicks" are very short sounds, often closely grouped. "Chatter" is a low intensity sound with an indefinite number of fairly regularly spaced pulse-trains, 70 to 110 ms apart. All sounds have the same frequency range, which is about the same as that of M. gracilis Hale and M. australiensis Chen. The pattern and rate of amplitude modulation is different in each species.

Observations of M. batilla during stridulation, and scanning EM observation showed that the strigil, a comb-like structure on

the sixth abdominal tergite of males, is almost certainly involved in stridulation. It is probably moved against the sharp edge of the fifth tergite (the "scraper"). Males of the two other species examined have strigils on the sixth abdominal tergite.

Experiments were carried out with groups of males, varying water volume and bottom area, and observations made of the relation between distance apart and sound production in pairs of males. Effects of changes of temperature, and of visibility, were studied. Mating was observed, and daily periodicity in sound production was studied by continuous recording.

Chirp and click scores increased with increasing temperature, up to 20°C, and decreased with poorer visibility and darkness. Chirping was optimal at about 20°C. There was a very high positive correlation between pulse-train rate and temperature, in chirps. Both chirps and clicks were maximal at sunrise and minimal at sunset. Chirping was about the same during day and night, but clicking occurred more during the day.

In groups of males clicking increased with decreasing area or volume, and chirps and clicks occurred more frequently as distance between two bugs decreased. Males clicked when bumped, or almost bumped, by another bug. Chirps are stimulated similarly, but are also stimulated by the presence of females in reproductive condition, and are used in mating. Females appear to be attracted to chirping males. Further observations suggested that sufficient conditions for mating are (a) a female in reproductive condition (physiologically), and (b) a male adult in sufficient water temperature to stimulate chirping, whether in reproductive condition or not.

The visual stimuli of other bugs are important in eliciting stridulation, although tactile stimuli may be more important for clicks. There is large individual variation in chirp activity, and some bugs chirp consistently alone or with another bug. There were quantitative and qualitative differences in sound production between crowded and more spaced bugs. It is suggested that chirping (a) is a premating isolating mechanism, and (b) may tend to hold groups of bugs together during the mating season.

(Ian's thesis also contains discussion of ecological aspects, based on observations on populations in the Cotter River, a tributary of the Murrumbidgee - Ed.)

PALAEOMAGNETICLIMNOLOGY

This rather improbable name may be used to describe an aspect of palaeomagnetism that is attracting an increasing amount of interest. Charles Barton and colleagues at the Research School of Earth Sciences, ANU, have lately been taking samples, using a Mackereth corer, of Lakes Keilambete, Gnotuk, and Bullenmerri in Western Victoria. They are also interested in any sources of information (water depth, sediment depth, age, etc.) for the

Tower Hill lakes, Mt Gambier lakes - especially Valley Lake - and Lake Leake and Lake Edward.

Little detail is yet known of the behaviour of the geomagnetic field in the last few tens of thousands of years. Archaeomagnetic measurements have proved extremely useful, but can only yield magnetic data at discernible points in time. A continuous record is, however, obtainable from lake sediments, which by the process of Depositional Remanent Magnetisation (DRM) are found to preserve traces of the ambient field direction at, or shortly after, the time of sedimentation.

Early measurements on Northern Hemisphere lakes were limited by glacial scouring to about 13,000 years BP, so attention has turned to lakes having a longer continuous record of sedimentation.

The main purpose of this type of work is the accumulation of data on the relatively recent short term variations of the geomagnetic field, but there is also the possibility of using magnetic profiles of sedimentary sequences as stratigraphic indicators.

In the latter case the requirement of a wet lake with a continuous record of sedimentation is no longer necessary, and dry lakes may prove to be of interest. Some preliminary work has been carried out on Lake Mungo, NSW.

LAKE BURLEY GRIFFIN

Terry Hillman recently completed his Ph.D. work on Lake Burley Griffin, Canberra, and has moved to Albury to join the team making an ecological survey of the River Murray, under the aegis of the Albury-Wodonga Development Corporation. What follows is a brief outline of Terry's thesis.

Lake Burley Griffin is a shallow ($\bar{z}$=4.7 m), turbid (secchi disc depth 0.4-2.4 m), artificial lake, 704 ha in area. It receives wastes - principally zinc - from an abandoned mine in the catchment of the Molonglo River.

The lake has a rapid rate of water turnover: approximately 5 times per year on average, although the rate in 1972-1973 was considerably slower. The lake is polymictic. The energy budget is markedly influenced by sediment heat storage, and by the throughput of water via the Molonglo.

Bioassays indicated that, for phytoplankton, phosphorus is the nutrient element most likely to be in short supply. Estimates of annual phosphorus loadings suggest that the nutrient status is between upper mesotrophic and eutrophic. However, carbon 14 measurements of phytoplankton production suggested an oligotrophic to lower mesotrophic status.

A number of environmental parameters were monitored in 1972-1973 and assessed by multiple regression analyses to

elucidate the factors influencing primary production by phytoplankton. Results indicated that turbidity and, to a lesser extent, zinc pollution and temperature are major controlling factors.

In the last six months of the study period, a number of buoyant and, in some cases, zinc-resistant algae became dominant. At this time primary production and biomass at the surface were typical of mesotrophic-eutrophic lakes. Increased numbers of cladocerans, particularly Daphnia carinata and Ceriodaphnia quadrangula, coincided with high surface phytoplankton biomass.

Turbidity is caused mainly by suspended particulate matter in the water, and appears to play an important part in the dynamics of zinc and other ions in the system.

Laboratory experiments showed that, depending on concentration, zinc may affect algae in any of three ways: by decreasing population growth rate, by reducing the rate of photosynthesis, or by increasing the rate of extracellular 'excretion'. Although each algal species tested reacted in this way, the degree of reaction varied considerably from species to species. Zooplankton species also varied in their zinc tolerance.

Changes in environmental factors may be reflected in the replacement of one dominant phytoplankter by another. These changes in 'dominance structure' appear to buffer planktonic primary production against environmental variability.

ADELAIDE HOME FOR THE PERMANENTLY PSYCHOLOGICALLY PUZZLED

Always remember that psychology tells us that when we think a thing the thing we think is not the thing we think but the thing that makes us think the thing we think we think. At least, I think I think it is. That is to say, when I think a thing I think the thing is not the thing I think but the thing I think makes me think the thing.